EXPLORATION OF THE RELATIONSHIP BETWEEN HIP RANGE OF MOTION AND ELBOW TORQUE IN COLLEGE BASEBALL PITCHERS

by

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Excessive elbow torque can cause injury to baseball pitchers' ulnar collateral ligament and require Tommy John Surgery. Due to the lengthy recovery process and decline in post-surgery pitching performance, research is needed to identify risk factors and ways to avoid this injury. The purpose of this study was to determine how differences in hip range of motion measurements between collegiate baseball pitchers related to the relationship between their pitching velocity and elbow torque. Pitching is a result of the kinetic chain transferring energy through the body, starting at the legs through the hand to throw the ball. When this kinetic chain does not work in unison to generate the force needed, part of the sequence in the chain will need to compensate for the lost energy. Having differences in modifiable physical factors, like hip range of motion, that can cause limitations within this kinetic chain could put the player at risk for injury. Therefore, it was hypothesized that pitchers that have a weak relationship between their pitching velocity and elbow torque will have greater hip range of motion. 96 subjects from several Division 1 college baseball teams participated in the study. Ball velocity and elbow torque were measured along with hip range of motion. Two groups were formed based on the individual pitchers' strength of relationship between ball velocity and elbow torque during pitching. These group's mean hip range of motion values were then compared. The results suggest that the group with a strong positive relationship between ball velocity and elbow torque had significantly limited hip range of motion compared to the group with a weak relationship. This study may be useful in guidance for baseball pitchers seeking to introduce a training regimen to reduce their risk of ulnar collateral ligament injury.

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INTRODUCTION

Elbow injuries are common among baseball pitchers with surgical repair of elbow ligaments, also known as Tommy John Surgery, taking out players for months on end. One strategy to curb this trend is for players to decrease the stress they are putting on their elbow, specifically the ulnar collateral ligament. There have been numerous studies conducted looking into how shoulder range of motion can affect pitchers' elbow stress; however, there is very little known about how the hips are related to this type of injury and injury prevention. Therefore, the purpose of this study was to determine how differences in hip range of motion measurements between collegiate baseball pitchers related to the relationship between their pitching velocity and elbow torque. It was hypothesized that pitchers that have a weak relationship between their pitching velocity and elbow torque will have greater hip range of motion.

Biomechanics

Biomechanics, in simple terms, is the study of the application of mechanical principals to biological systems. This knowledge can be applied to nearly all aspects of life but can also be specifically applied to sports. Sports biomechanics focuses on improving an athlete's movement in order to enhance performance as well as minimize injuries.

Torque is a term used in biomechanics to refer to the turning, or rotational, effect produced by force (McGinnis, 2020). Stress is used in biomechanics to refer to internal or external forces that exert stress on the body. Both torque and stress can be directed in different directions: valgus and varus. Valgus indicates that the force is initiated on the lateral, or outer, side of the body and directed inward and varus indicates that the force is initiated on the medial, or inner, side of the body and directed outward. Elbow varus torque, specifically, is of interest in baseball pitchers (Camp et al., 2017). The elbow ligaments utilize varus torque to resist valgus stress during the arm cocking phase of the pitching motion. The valgus stress being applied at the elbow causes compression on the lateral part of the elbow and gapping, or opening up, on the medial part of the elbow. The medial elbow ligaments are put under greater tension when there is more gapping due to the increased need for the resistive torque. When the elbow varus torque increases, that indicates that there are higher levels of valgus stress being applied to the joint which can lead to injury.

Significance and Background

America's greatest pastime of baseball is taking a toll on its players, pitchers specifically. As of 2015, 25% of all Major League Baseball and 15% of Minor League Baseball pitchers have a history of Tommy John Surgery, which is performed on players that need their ulnar collateral ligament (UCL) reconstructed (Conte et al., 2015). The UCL is located on the medial, or inner, aspect of the elbow connecting the humerus and the ulna (Figure 1).

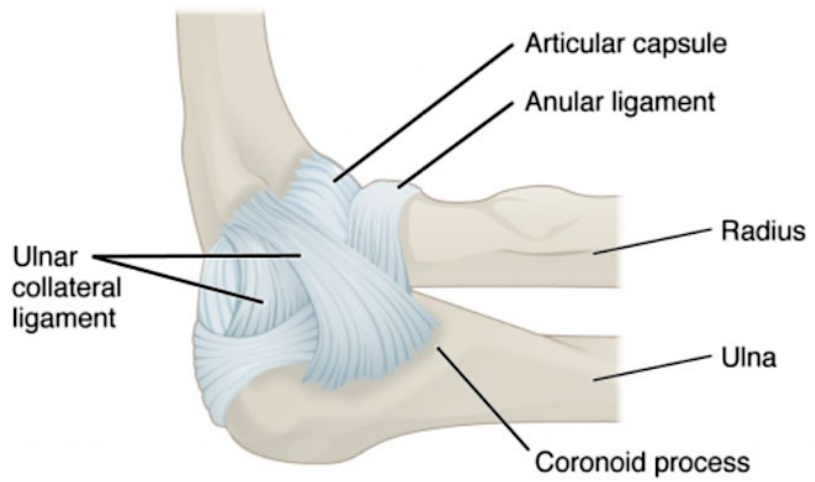

Figure 1: The location of the Ulnar Collateral Ligament at the elbow joint. (Biga et al., 2019)

The UCL has been identified as the key stabilizer of the elbow during overhead athletics and can suffer tears from excessive, repetitive valgus stress caused by the pitching motion (Safran et al., 2005). With this injury being so widespread, risk factors like differences in shoulder range of motion, pitching velocity, and years of experience are being identified in hope of reducing this injury (Reiman et al., 2019).

Not only is Tommy John Surgery affecting a great number of players, but it also has major impacts on post-surgical performance. A 2014 study examined 147 MLB pitchers who underwent Tommy John Surgery (Makhni et al., 2014). This surgery takes players away from the game for an extended period of time with an average of 17 months found in this study. With such an extensive recovery time, it would be expected that players come back ready to compete at their highest level. However, the reality is that returning from UCL reconstruction, pitchers showed a significant decrease in performance in several areas including pitching in the strike zone, percentage of fastballs pitched, and average fastball velocity (Makhni et al., 2014). Another study conducted a systematic review and meta-analysis of 22 different studies to analyze the rate of return to play of baseball pitchers after UCL injury and surgery (Peters et al., 2018). Their findings suggest that while the rate of return to sport was high at 90%, the return to play at pre-injury level was lower at 79%, pitchers showed a reduction in fastball velocity, and a significant decrease in innings pitched over a season. These findings enforce the notion that the lengthy return to play process and decreased quality of pitching are glaring reasons that UCL injury prevention should be taken seriously in baseball pitchers. Understanding the full extent of risk factors and how players can manage them are crucial to this goal.

The Kinetic Chain of Pitching

Pitching in baseball is the result of a kinetic chain, with the transfer of energy starting at the lower extremity (leg, ankle, foot) and transferred through the upper extremity (arm, wrist, hand) until the ball is released from the hand. The phases of pitching involve the windup, early cocking, late cocking, acceleration, and follow through (Figure 2).

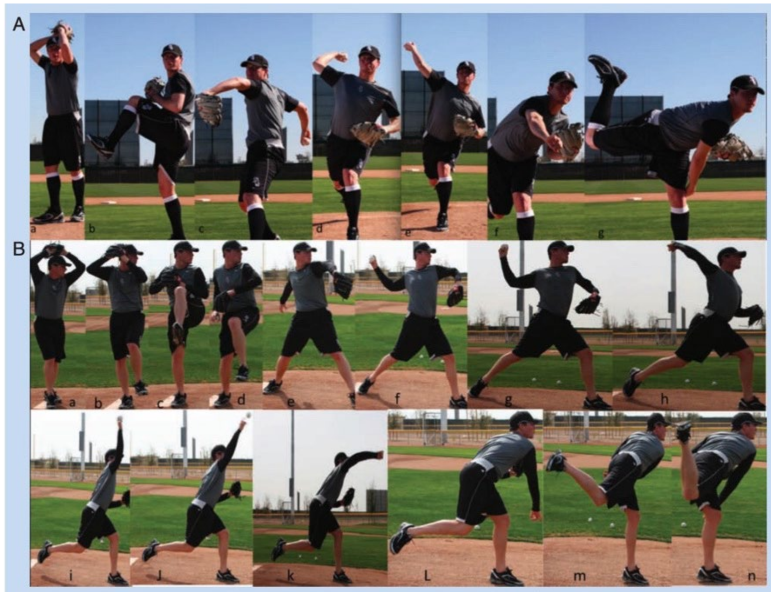

Figure 2: Line A shows the pitch from a front view, (a, b) windup, (c) early cocking, (d) late cocking, (e) acceleration, (f,g) follow through. Line B shows the pitch from a side view, (a-c) windup, (d-e) early cocking, (f,g) late cocking, (h-j) acceleration, (k-n) follow through (Seroyer et al., 2010).

For a pitcher to achieve his highest velocities, every part of the pitching phases must coordinate to transfer kinetic energy through the body. Starting at the lower limbs in the legs and hips, potential energy goes up through the torso, to the shoulder, elbow, and hand, and is converted into kinetic energy, sending the baseball out of the pitcher's hand and into the catcher's glove. When this kinetic chain does not work in unison to generate the force needed, some part of the body will need to compensate to make up for the lost energy lower in the sequence. For example, one study calculated that a decrease of just 20% of kinetic energy by the hip and trunk caused the shoulder to increase its kinetic energy production by 34% to offset what was lost in the lower limbs (Kibler & Chandler, 1995). Having differences in modifiable physical factors, such as strength or range of motion, that cause limitations and create obstacles within this kinetic chain could cause a decrease in pitch velocity and even put the player at risk for injury due to repeated overcompensation and overuse of their muscles, ligaments, and joints.

Pitch Velocity as a Risk Factor

Ball velocity is both a critical component in the performance of a pitcher and a likely danger to the health of a pitcher's UCL. The fastball specifically has been singled out as the pitch that poses the most risk for injury because it is the pitch with the highest velocity (Chalmers et al., 2016). It seems intuitive that pitching faster would increase the stress on the elbow and therefore increase the risk of injury. In fact, there is evidence suggesting a positive correlation between pitch velocity and elbow torque (Bushnell et al., 2010). Confirming this relationship would paint a clear picture that in order to reduce UCL injury, pitchers would simply need to slow down their pitches. However, it is not that simple. Above all, pitchers do not want to reduce their pitch velocity and perform below their abilities in their competitive field. Furthermore, other studies show contrasting findings that did not find a definitive relationship among pitchers' increased velocity increasing elbow torque (Post et al., 2015). This discrepancy leads us to question if differences between pitchers are affecting this relationship between pitch speed and elbow stress. Determining the physical differences between pitchers that do have a positive correlation between pitch velocity and elbow stress and those that do not could lead to a strategy to help ensure that pitchers do not have to sacrifice their high velocities and pitching performance for the prevention of injury.

The Focus on the Shoulder Versus the Hip

In addition to ball velocity, researchers have focused heavily on how the shoulder affects elbow stress and UCL injury. Studies have identified a relationship between injuries of baseball players' elbows and deficits in their shoulder range of motion (Garrison et al., 2012; Wilk et al., 2014). These studies specifically found that deficiencies in total range of motion, being the mathematical sum of external and internal range of motion, put the pitcher at higher risk for elbow injury. This lack of mobility at the glenohumeral joint of the shoulder can cause a disturbance in the kinetic chain involved in pitching meaning that somewhere further down the chain, in this case the elbow, will have to pick up the slack.

As for the hips, there are a limited number of studies involving baseball pitchers. Studies show that pitchers that had sustained upper limb injuries decreased hip external range of motion and abduction strength on their dominant side (Hamano et al., 2021). Another study found a correlation between professional pitchers sustaining lower extremity injuries later requiring UCL reconstruction (Kantrowitz et al., 2018). While studies like these are available, they often are limited in their specific connection and application to the UCL and instead generalize upper limb injuries. They also often put more focus on injuries rather than on standard, measurable physical factors. Focusing on physical factors that players can take an active role in modifying, like hip range of motion, in connection to UCL injury will provide pitchers with guidance to reduce their risk of injury while being able to perform at their highest level.

METHODS

Participants

Ninety-six Division 1 collegiate baseball pitchers (age: 20.4 ± 1.8 yr, height: 1.8 ± 0.05m, weight: 90.5 ± 6.9 kg) from five universities (University of Oregon, UCLA, USC, UCSB, Pepperdine University) participated in this study. All participants provided informed consent prior to testing. This study was approved by the Institutional Review Board.

Instrumentation

Hip range of motion was measured using an Acumar digital inclinometer (Lafayette Instrument, https://lafayetteevaluation.com). This device provides measurements of angles up to 360°, measuring +180° to -180°, in real time. This digital inclinometer was aligned vertically against a flat surface to serve as a reference point of 0° before measurements. Ball velocity was measured using a radar gun (Jugs Tribar Sport radar gun; Jugs Pitching Machines Co, Tualatin, Oregon). The radar gun was positioned on a tripod at approximately the level of the release of the ball during a pitch behind the catcher. Elbow stress was measured using the motusBASEBALL sleeve, sensor, and application (Motus Global, https://motusglobal.com/motusbaseball.html). The sensor is an inertial measurement unit (IMU) that is able to measure joint angles and acceleration to determine the peak elbow valgus torque in Newton-meters. Individual pitcher data, name, date of birth, height weight, and handedness was entered into the motusTHROW app prior to data collection. This system tracks the elbow stress during each pitch and wirelessly saves it to each pitcher's profile on the application.

Procedures

Data from all five teams were combined. Players participated in collection of physical measures and live bullpen pitching on separate days. Physical measures taken consisted of hip range of motion, shoulder range of motion, shoulder strength, hip abduction strength, a balance task with an auditory component, ultrasound of the shoulder, grip strength, trunk-pelvis disassociation, and unilateral hip bridge. During live bullpen pitching, ball velocity and elbow stress were measured.

The physical measurement that was the focus of this project was passive hip range of motion, internal, external, and total, for both the lead leg and trail leg. The lead leg is on the same side of the body as the glove and is out front of the body during the pitch while the trail leg is on the same side as the ball and is planted on the mound during the pitch. For both the internal and external range of motion measurements, players were in a prone position (lying flat with their chest down) with their trunk and pelvis aligned. They were instructed to bend their knee, relax their legs, and that they should not assist or resist movement during testing. The tester placed one hand on the player's posterior-lateral-superior pelvis to monitor pelvic motion while using the other hand to facilitate the hip movement. To measure hip internal rotation, the tester passively moved the leg laterally until end range of motion was hit or the pelvis started to move. This position was held, and the angle was measured with the digital inclinometer aligned with the tibia (Figure 3).

Figure 3: Photograph of experimental setup measuring internal hip range of motion.

To measure external rotation, the tester passively moved the leg medially until end range of motion was hit or the pelvis started to move. Again, this position was held, and the angle was measured with the digital inclinometer aligned with the tibia. This procedure was repeated three times for both legs.

Ball velocity and elbow stress were measured synchronously during bullpen pitching. Ball velocity was measured using a radar gun placed directly behind the catcher and was recorded after every pitch. Elbow stress was measured using the motusBASEBALL system. To attach the sensor, the pitcher placed his throwing arm outstretched with the palm facing up. After finding the medial epicondyle, a bony prominence on the humerus, the sensor's proximal edge was placed two finger-widths below the medial epicondyle with the arrow pointed distally and the serial numbers facing into the arm. The sensor was fixed onto the arm using cover-roll and/or leukotape. The motus sleeve was then placed on the arm covering the sensor. The sensor was connected to the motusTHROW app via Bluetooth and the active pitcher's profile was used to collect and save the data to. Pitchers conducted their own individual mobility warm-ups which was consistent with their typical routine prior to bullpen pitching. They were allowed to stretch and throw as many warm-ups as they wanted. Following their warm-up, each pitcher threw ten consecutive fastball pitches which we collected their ball velocity and elbow stress from.

Statistical Testing

The correlation between ball velocity and elbow torque of ten pitches was calculated for each individual subject using Excel. Subjects were then split into two groups depending on the r value that was identified and the strength of this correlation: group 1 having a strong positive correlation ($r \geq 0.7$) (Figure 4) and group 2 having a weak/no correlation ($r < 0.7$) (Figure 5). The r value threshold to indicate a strong relationship was determined to be 0.7 based upon the Dancey and Reidy correlation coefficients that are widely used in statistics (Akoglu, 2018). Using SPSS, six independent samples t-tests were run to determine if there was a statistically significant difference between the group averages regarding internal range of motion of the trail leg, internal range of motion of the lead leg, external range of motion of the trail leg, external range of motion of the lead leg, total range of motion of the trail leg, and total range of motion of the lead leg. All t-tests utilized a 95% confidence interval and P-values of <0.05 were considered to be significant results.

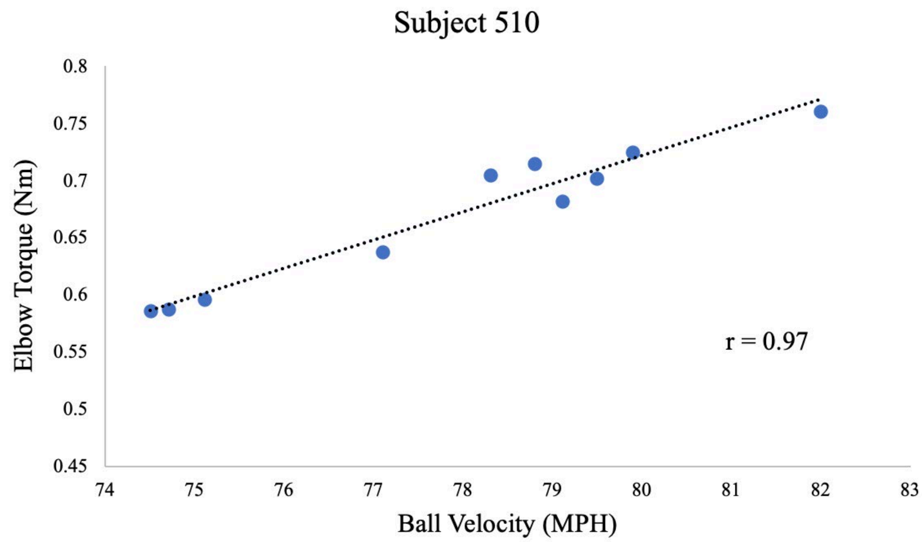

Figure 4: Example of correlation between elbow torque and ball velocity for a subject in group 1

Subject 510 had a calculated r value of 0.97 meaning that there was a very strong positive correlation between increasing ball velocity and increasing elbow torque. This relationship indicates that as this player increased his ball velocity, there was a corresponding increase in stress at his elbow.

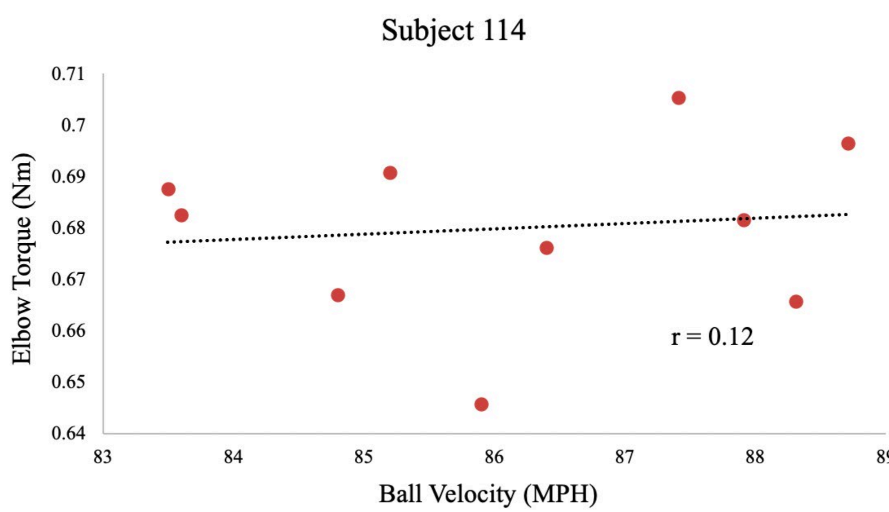

Figure 5: Example of correlation between elbow torque and ball velocity for a subject in group 2

Subject 114 had a calculated r value of 0.12 meaning that there was a very weak positive relationship between increasing ball velocity and increasing elbow torque. This indicates that there is not a predictable or consistent increase in stress at the elbow when this player increased his ball velocity during a pitch.

RESULTS

Of the 96 pitchers participated in this study, 81 had the necessary measurements and information available for analysis. Group 1 ($r \geq 0.7$) included 32 pitchers for which all six variables were measured. Group 2 ($r < 0.7$) included 48 pitchers for which all six variables were measured. Group 2 also included one pitcher for which only five variables were measured, and internal range of motion of the lead leg was excluded due to insufficient data

Internal Range of Motion

Group 2 showed a significantly greater internal range of motion of the lead leg ($p = .002$). Group 1 had a mean value of 33.1 ± 8.1˚ and group 2 had a mean value of 40.6 ± 12.5˚ (Figure 6). Group 2 showed a significantly greater internal range of motion of the trail leg as well ($p = .019$). Group 1 had a mean value of 34.1 ± 8.7˚ and group 2 had a mean value of 39.1 ± 9.9˚ (Figure 7).

External Range of Motion

Group 2 showed a significantly greater external range of motion of the lead leg ($p = .001$). Group 1 had a mean value of 46.4 ± 10.6˚ and group 2 had a mean value of 56.6 ± 16.9˚ (Figure 8). Group 2 also showed a significantly greater external range of motion of the trail leg ($p < .001$). Group 1 had a mean value of 46.6 ± 12.2˚ and group 2 had a mean value of 58.2 ± 16.4˚ (Figure 9).

Total Range of Motion

Group 2 showed a significantly greater total range of motion of the lead leg ($p < .001$). For the lead leg total range of motion, group 1 had a mean value of 79.5 ± 12.2˚

and group 2 had a mean value of 97.8 ± 23.8˚ (Figure 10). Group 2, again, showed a significantly greater total range of motion of the trail leg ($p < .001$). For the trail leg total range of motion, group 1 had a mean value of 80.8 ± 15.0˚ and group 2 had a mean value of 97.4 ± 22.5˚ (Figure 11).

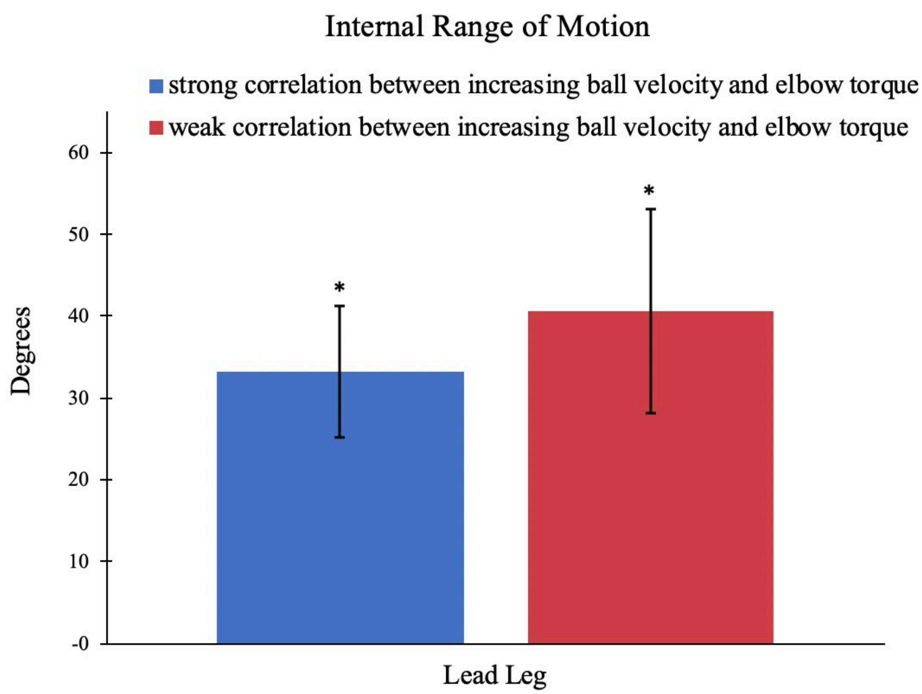

Figure 6: Average internal range of motion of the lead leg for pitchers with a strong correlation between ball velocity and elbow torque and pitchers with a weak correlation between ball velocity and elbow torque

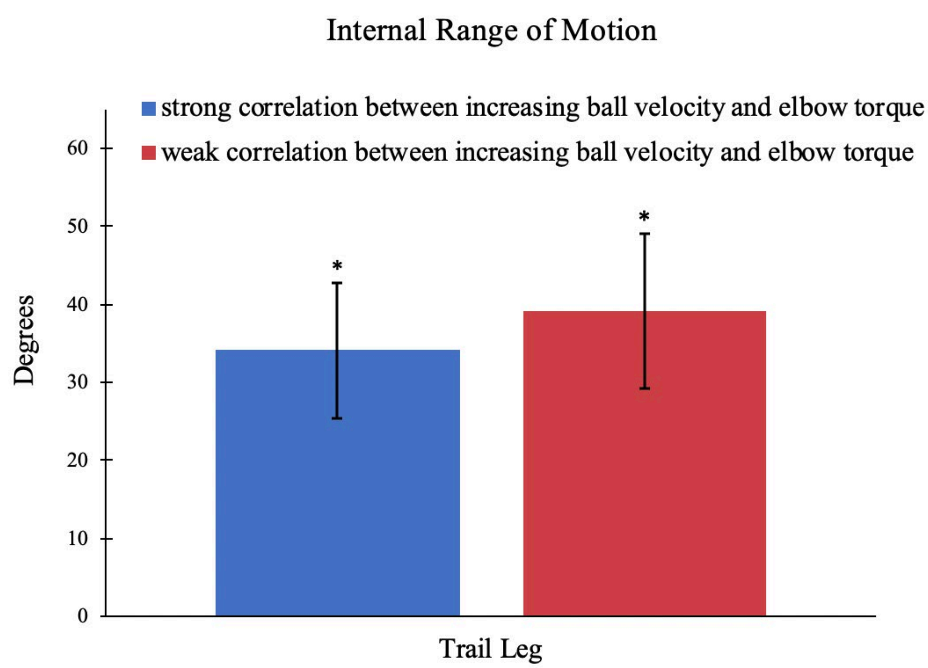

Figure 7: Average internal range of motion of the trail leg for pitchers with a strong correlation between ball velocity and elbow torque and pitchers with a weak correlation between ball velocity and elbow torque

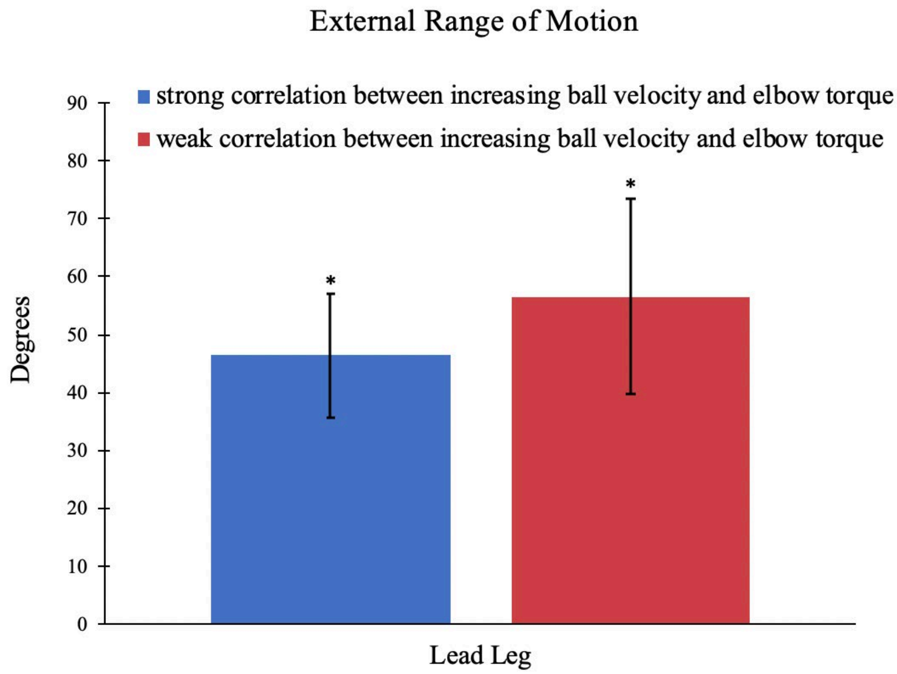

Figure 8: Average external range of motion of the lead leg for pitchers with a strong correlation between ball velocity and elbow torque and pitchers with a weak correlation between ball velocity and elbow torque

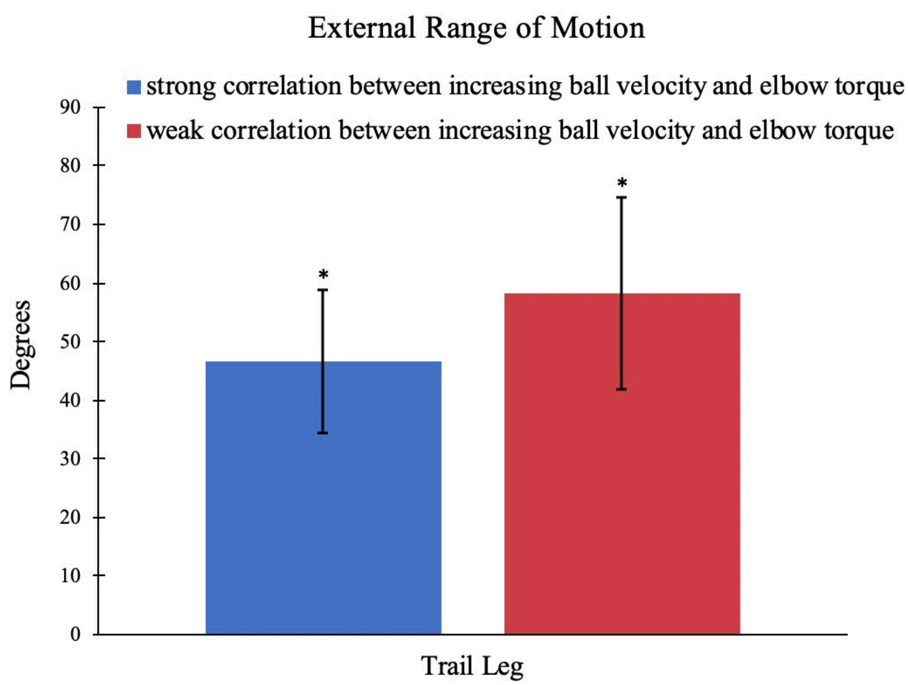

Figure 9: Average external range of motion of the trail leg for pitchers with a strong correlation between ball velocity and elbow torque and pitchers with a weak correlation between ball velocity and elbow torque

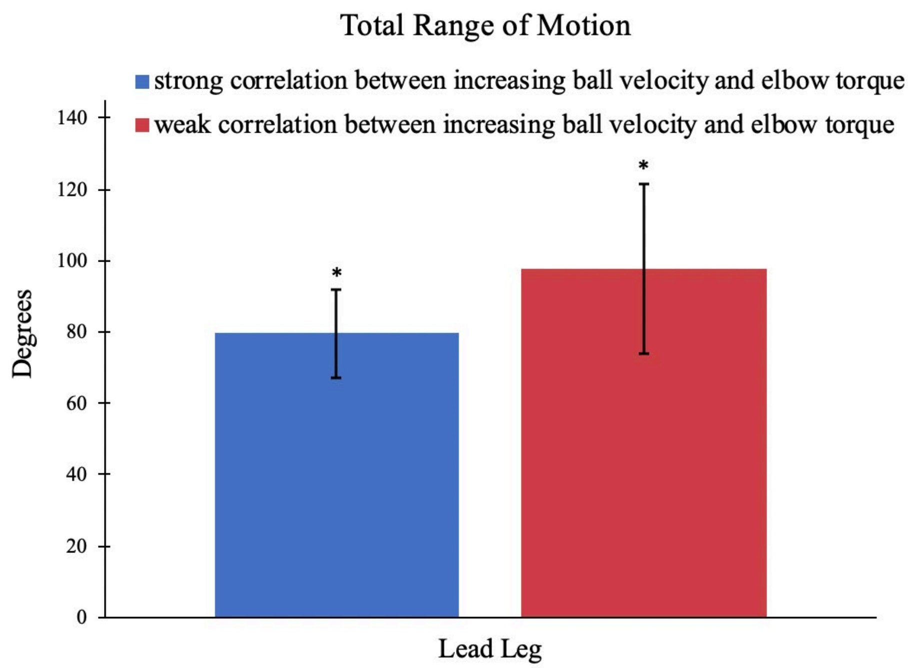

Figure 10: Average total range of motion of the lead leg for pitchers with a strong correlation between ball velocity and elbow torque and pitchers with a weak correlation between ball velocity and elbow torque

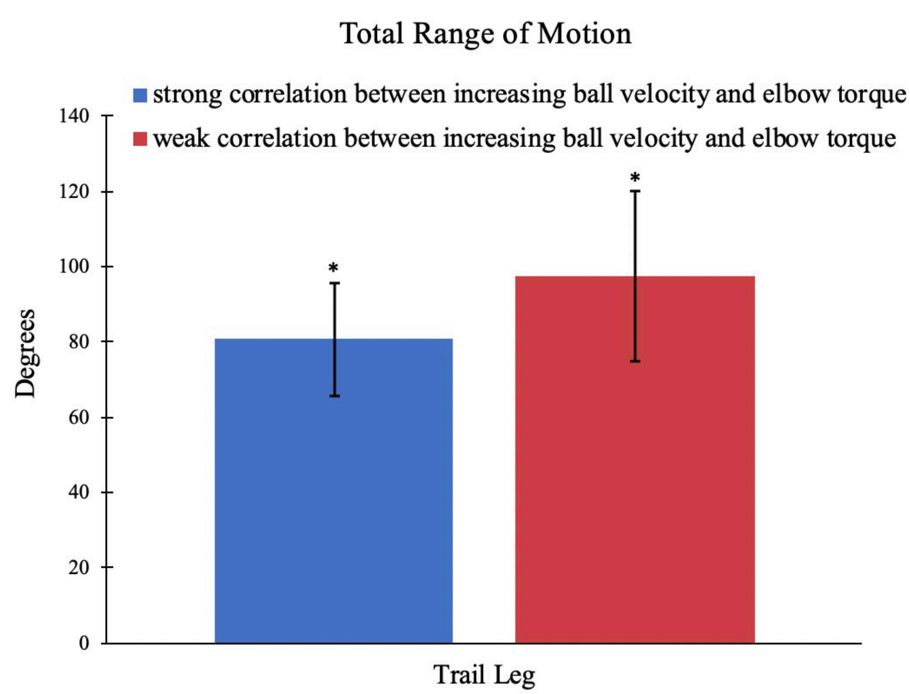

Figure 11: Average total range of motion of the trail leg for pitchers with a strong correlation between ball velocity and elbow torque and pitchers with a weak correlation between ball velocity and elbow torque

DISCUSSION

The purpose of this study was to identify how differences in hip range of motion measurements between collegiate baseball pitchers related to the relationship between their ball velocity and elbow torque during pitching. Previous studies described restricted hip range of motion as a limiting factor in the kinetic chain of pitching and a risk for upper limb injury (Hamano et al., 2021; Kibler & Chandler, 1995). Therefore, it was hypothesized that pitchers who had a weak relationship between ball velocity and elbow torque during pitching would have a greater hip range of motion. The current study supports the hypothesis, having identified a significant difference in hip range of motion between pitchers with a weak relationship and a strong relationship between ball velocity and elbow torque. Pitchers with a weak relationship had larger mean values for hip range of motion for internal, external, and total range of motion of both the lead and trail leg.

The current findings suggest that there may be an association between a decrease in hip range of motion and an increase in elbow torque during the pitching motion. Internal range of motion was found to be lower in pitchers who had a strong association between increasing elbow torque and ball velocity for both the lead and trail leg. This is consistent with prior research conducted on youth pitchers examining elbow pain associated with restricted lead and trail leg internal hip rotation (Saito et al., 2014; Sekiguchi et al., 2020). Decreased external range of motion was also identified in pitchers who had a strong relationship between increasing elbow torque and ball velocity for both the lead and trail leg. A 2021 study of collegiate pitchers suggested that a decrease in trail hip external range of motion would restrict the pitcher’s trunk to move forward over their lead leg, causing a disruption in the kinetic chain (Zeppieri Jr. et al., 2021). This supports the basis of the hypothesis of the current study which explains that a reduction in hip range of motion could decrease the amount of energy transferred from the lower extremities to the upper extremities and cause the elbow to compensate for that loss and potentially be at risk for injury.

Since hip range of motion is a clinically modifiable factor, pitchers could establish a training regimen to improve their hip range of motion in order to potentially reduce the risk of UCL injury based on the association found in this study. Future studies can observe how implementing such a training regimen would affect athletes to examine if it does reduce the risk and number of UCL injuries in pitchers in order to substantiate this claim.

Limitations

One possible limitation is that subjects had no restrictions of the activities they could engage in prior to testing. Having no control around this meant that subjects may have engaged in activities such as stretching or working out that could have affected their hip range of motion in the short term and altered their measurements. Another possible limitation is that multiple universities participated in collecting the data meaning that several individuals took subjects' hip range of motion measurements. This could have potentially caused a lack of consistency in how the measurements were taken and therefore affected the measurements. However, to address this concern and minimize errors there were detailed documented procedures as well as training including reliability testing to ensure consistency of measurements regardless of who was collecting the data.

Future Directions

The current study focused on passive range of motion, meaning the subject had their legs moved for them and did not need to engage their muscles to produce movement of the hips. It could be beneficial for future studies to focus on active range of motion, meaning the subject causes hip rotation without the assistance of the tester. This could possibly better mimic the movement of the hips during a live pitch since in both situations the subject is producing hip rotation on their own.

Future studies may also consider focusing on pitchers that lie on the extreme ends of the correlation between ball velocity and elbow torque. By doing so, researchers may be able to more clearly distinguish meaningful discrepancies between pitchers and recommend target goals for improvements in hip range of motion. For example, comparing two pitchers with r values of 0.8 and 0.2 might give a more definitive difference in hip range of motion values than comparing two pitchers with r values of 0.7 and 0.6. To accomplish this, researchers would need to exclude pitchers that fall in the middle ground with moderate r values, and instead focus their testing on pitchers that have very strong or very weak relationships between ball velocity and torque.

CONCLUSION

From these findings, it appears that pitchers with limited hip range of motion have a strong relationship between increasing ball velocity and increasing elbow torque, implying that these pitchers are at a higher risk for UCL injury. This suggests that pitchers should work to increase their hip range of motion in order to reduce UCL injuries without sacrificing pitching performance.

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